THE ASSESSMENT OF NEW PLATFORMS ON OPERATIONAL PERFORMANCE AND MANNING CONCEPTS

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ABSTRACT

During the various phases of the Defence acquisition process, and in the early design phases, many decisions must be made concerning the performance, crew configuration and cost of new equipment, e.g. new naval platforms. In practice many of these decisions are made either based on a limited view on their impact or based on subjective information. Moreover, previous studies have shown that the impact of the decisions taken in the early design phases is large; they generally determine as much as 80% of the total life cycle costs. This highlights the importance of decision making support in these areas.

In case of the acquisition of new equipment, the various alternatives must be assessed on performance and costs, and the constitution of the crew needed for operating the equipment has to be determined. In case of the design of new platforms also the design issues have to be addressed. This assessment can be done at various levels of detail: performance of the platform during its lifetime in various missions, but also the composition and performance of the crew during specific tasks.

TNO has developed two methodologies to support the acquisition and design process of new equipment and the assessment of manning concepts: the manning concept framework and the Simulation Based Performance Assessment (SBPA) methodology.

Together these methodologies constitute a toolbox to support the process of designing a new platform or upgrading an existing platform on both the technical and the human components.

1 INTRODUCTION

The operational environment of the Dutch Ministry of Defence (NL MoD) is very dynamic and complex. The nature of the missions changes, advanced technology plays a large role and the number of people with which the missions can be carried out, decreases. The NL MoD strives for an optimal balance between operational effectiveness and life cycle costs of its materiel. Because of the sea platform requirements of the Royal Netherlands Navy (RNLN), the RNLN fulfils the role of smart designer and smart integrator during the acquisition process. The RNLN acts as smart designer of its platforms and as smart integrator of the Sensor, Weapon and Command (SEWACO) systems. The Royal Netherlands Air Force and Royal Netherlands Army usually act as smart buyer.

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During the various phases of the Defence acquisition process, and in the early design phases, many decisions must be made concerning the performance, crew configuration and cost of new equipment, e.g. new naval platforms. In practice many of these decisions are made either based on a limited view on their impact or based on subjective information. Moreover, previous studies have shown that the impact of the decisions taken in the early design phases is large; they generally determine as much as 80% of the total life cycle costs. This highlights the importance of decision making support in these areas. In case of the acquisition of new equipment, the various alternatives must be assessed on performance and costs, and the constitution of the crew needed for operating the equipment has to be determined. In case of the design of new platforms also the design issues have to be addressed. This assessment can be done at various levels of detail: performance of the platform during its lifetime in various missions, but also the composition and performance of the crew during specific tasks. TNO has developed two methodologies to support the acquisition and design process of new equipment and the assessment of manning concepts: the manning concept framework and the Simulation Based Performance Assessment (SBPA) methodology. Together these methodologies constitute a toolbox to support the process of designing a new platform or upgrading an existing platform on both the technical and the human components.

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The NL MoD uses various techniques to support various forms of design and re-design processes. For instance during the acquisition process (‘Defensie Materieel Proces’, DMP), during the maintenance and modernization programmes, and during the implementation of modifications and for doctrine-related questions, The use of these techniques is currently somewhat fragmented and is primarily aimed at the operational assessment of specific subsystems.

In order to support better decision making during the various forms of design and re-design processes, the Netherlands Organisation for Applied Scientific Research TNO has developed both the manning concept framework and the Simulation Based Performance Assessment (SBPA) methodology that can support an integral and systematic approach on both technical and manning aspects at various design levels.

At platform level the SBPA methodology enables the determination of the overall performance of a platform. It considers the operational effectiveness, survivability, sustainability, and life cycle costs. These aspects are compared in a transparent and unbiased manner. In this way, the SBPA methodology enables to perform trade-offs between different design alternatives and thus allows well-informed acquisition decision-making. An integrated performance assessment is supported by simulation models, since they enable the evaluation of the system as a whole beforehand and reduce the risks and costs of real-life experimentation.

Manning plays an important role in the performance of a platform and the design choice of manning concept will have a large influence on the (operational) effectiveness of the platform and its associated development and life cycle costs. Therefore, the design and acquisition process of a platform requires an integrated approach in which the manning concept should be aligned with the technical possibilities to meet the overall functional and performance requirements which are set in the initial design phase. Furthermore, design alternatives should be considered in light of the pay-off between effectiveness and associated development and life cycle costs. The manning concept framework is an integrated and systematic approach that utilizes the design of manning concepts and supports the decision making process when considering design alternatives at the various design level, including the relationship between ship design and manning concepts.

This paper presents the manning concept framework and the SBPA methodology and shows how these are related and how they can concurrently be used in a design process.

The remainder of this paper is organised as follows. Sections 2 and 3 introduce the manning concept framework and the SBPA methodology. Section 4 describes how they are related. Finally, we present our conclusions.

2 MANNING CONCEPT FRAMEWORK

This section describes the manning concept framework shown in Figure 1. A more extensive description can be found in Reference [8]. The framework consists of four interconnected design levels:

- strategic ambition;
- functional demands;
- conceptual design;
- detailed design.

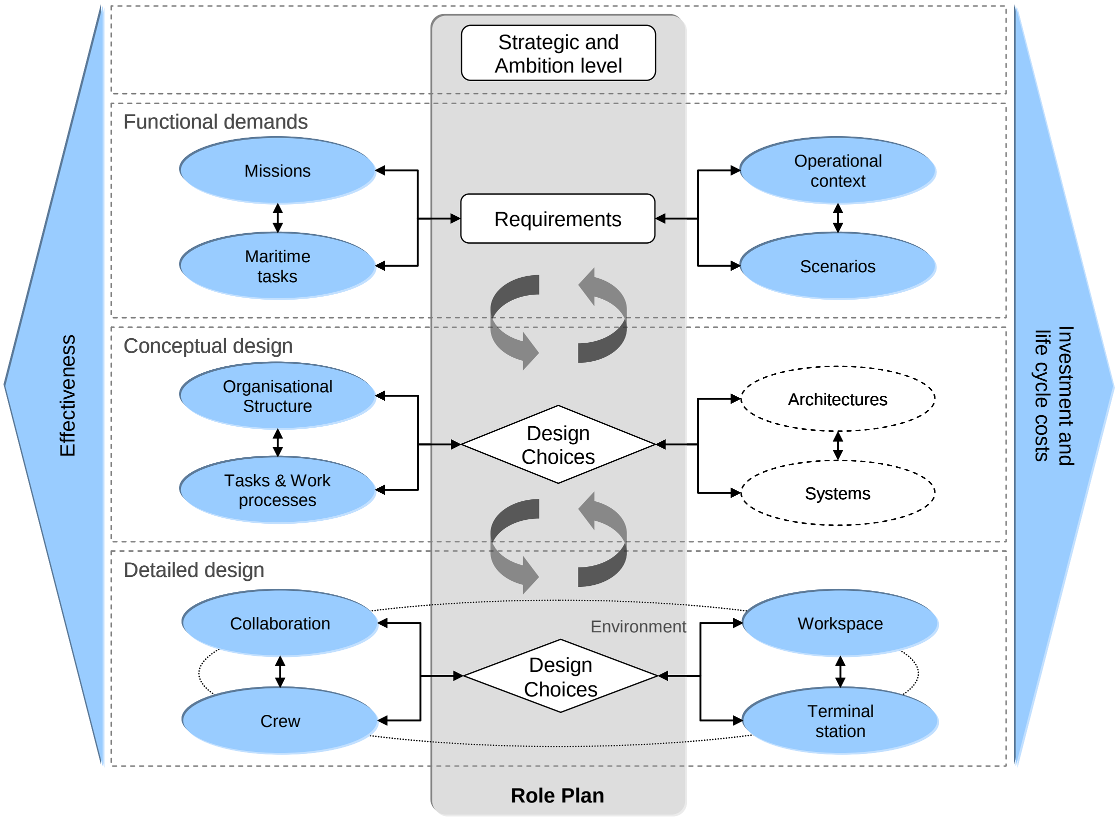

Figure 1: The manning concept framework.

Each level views the platform at a different level of aggregation. It means for instance that on the functional demands level considerations are made regarding the deployment of a platform and that at the detailed design level job designs of a single crew member are established as well as the operations room lay-out. Factors within one level a strongly interconnected, e.g. at conceptual design level the choice of an organisational structure influences the tasks and work processes. Breaking the design process down into four design levels is *one design principle* that has been applied.

The *second design principle* is that the levels are interconnected. It means that the choices made on one level constrain the design choices on subsequent levels. Constraints have to be relaxed on a higher level when they can not be matched within the associated development and life cycle costs boundaries on subsequent levels. It could mean that initial ambition levels and task execution concepts have to be reconsidered because they are not realistic in terms of crew size and costs.

The *third principle* applied, is that at each level design alternatives can be compared in terms of their effectiveness and associated development and life cycle costs. Because the design levels vary concerning their level of aggregation also the cost and effectiveness indications vary in precision. At a high aggregation level only relative changes can be indicated, where on the detailed design level more detailed and absolute indications can be provided.

It is important to note that the manning concept framework does *not* generate design solutions, but it is supportive to the design process carried out by humans and improves their decision-making. It is supportive because it provides an integrated overview of the design process, it shows the interconnection between various design choices at various levels, and it allows that the rationales behind design choices are made explicit and well documented.

It improves decision-making because the frame work allows pay-off consideration between investment and development costs on the one hand and life cycle costs on the other hand. Furthermore, by applying the framework the feasibility of what is wanted (ambition and functionality) at what price (manning and technology) can be established during the design process instead of only finding out in the operational phase of a platform. The framework helps to decrease the possibility of operational and financial setbacks.

2.1 Strategic ambition

The acquisition of a new platform starts with the strategic ambition. The strategic ambition is usually based on political decisions regarding the deployment of the armed forces and their main assets. These political decisions give direction to the design process and provide the preconditions that the design must meet. The strategic ambition includes aspects such as:

- Level of violence in which the platform has to operate.
- Task performance: does the platform have to carry out its main tasks simultaneously or one main task at a time? Can external support be called upon?
- Endurance ambition: how long should the platform be able to operate without external support and supply?
- Technology level: is advanced technology requested or is a ‘simple’ platform good enough.
- Reliability, Availability, Maintainability (RAM): Is a high level of RAM required or not?
- Training: can be ashore or on board, whether or not supported by coaching.
- Is the crew size constrained or not?

The other three levels are the “real” design levels. In general we can characterise the levels by the focus of the design:

- Functional: functioning of the platform itself
- Conceptual: functioning of manning teams
- Detail: functioning of a single crew member

2.2 Functional demands

The functional demands describe the functions the platform as a whole should be able to execute. They describe the missions and tasks that the platform has to carry out, e.g. coast guard, maritime interdiction, Anti Submarine Warfare. The scenarios in which the platform is expected to operate and to carry out these missions are also part of the functional demands level. For each of the tasks, Measures of Effectiveness (MOEs) are defined that can be used to evaluate the design. Minimum requirements to these MOEs (the functional demands) can lead to limiting conditions for the conceptual and detailed design levels. The evaluation at this level is most closely related to the SBPA methodology, which will be described in Section 3.

2.3 Conceptual design

At the conceptual design level, the functional demands are translated to working methods: the main structure of the work organisation including specific working processes. Because the conceptual design level is right between ambition and functional demands on one side and (practical) detailed design solutions on the other side, it can be seen as the most creative process in which innovative solutions can be sought. Aspects of the manning concepts that occur at this level are the organisation structure, procedures, team tasks and processes, allocation of tasks to crew members, the technical environment and

architectures. Examples of a conceptual design are an integrated command bridge, modular teams etc. The choices that will be made at the conceptual design level are the limiting conditions for the detailed design.

2.4 Detailed design

In the detailed design phase choices made at the higher levels are tested on feasibility and desirability by assigning people and resources. Organisation structures, working procedures and tasks as described at the conceptual design level are further elaborated. For instance: cooperation between individuals is assessed, tasks are assigned to individuals, and the working environment is evaluated.

Conceptual design and detailed design are worked out in an iterative way until a feasible and acceptable manning and technology plan is obtained.

2.5 Linking functional demands and conceptual design

The tasks of the platform at the functional demand level are connected with the manning concept aspects at the conceptual design level. However, a direct connection is difficult to obtain. Therefore seven clusters have been identified. These clusters each have influence on the platform tasks at the functional demand level. On the other hand, the clusters can be more easily identified and linked to conceptual designs, e.g. because a cluster corresponds to one or more teams. The identified clusters are:

- Command and Control (C2);
- Intelligence, Surveillance and Reconnaissance (ISR);
- Manoeuvre;
- Logistics & Sustainability;
- Weapon Deployment;
- Force Protection;
- System management & Damage Control.

Table 1 gives an example of possible relationship between tasks and the functional demand level and the identified clusters. In this table, the symbols indicates the strength of the relationship between the cluster in the corresponding column and the task in the row, where + and ++ mean a strong relationship, = an average relationship (it has influence, but not decisive on the performance of a task), and - and -- indicate that there is only a weak relationship or no relation at all.

Table 1: Example of the relationship between tasks and clusters

	C2	ISR	Manoeuvre	Logistics	Weapon deployment	Force protection	System management
Detection	=	++	=	-	-	--	-
Interception	=	=	++	-	=	--	-
Boarding	=	-	+	-	=	+	-
Sustainability	--	--	--	++	--	=	++
Survivability	=	=	=	--	+	++	+

2.6 Evaluating costs and effectiveness

Manning concepts are evaluated on effectiveness and costs. Especially at a conceptual and detailed design level, quantifying effectiveness is difficult. Therefore, a qualitative evaluation is usually carried out. During this evaluation, concepts are compared to each other and for all aspects at a level, it is indicated if a design performs (much) better or worse than the base case design. This is illustrated by a colour coding analogous to the system of a traffic light. An example of such an evaluation can be found in Figure 2. Green means a positive effect, orange and red a (strong) negative effect. In white is indicated that there is no difference, a grey shadings means that the effect is unknown and further investigation is required.

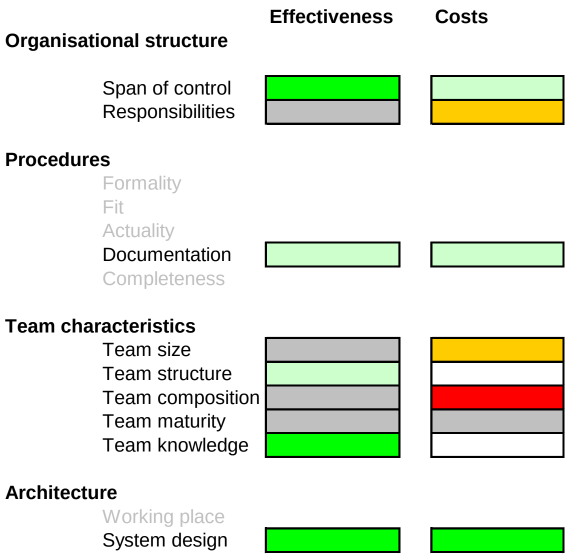

Figure 2: Qualitative evaluation at conceptual design level.

2.7 Role plan

If a manning concept is feasible and cost effective at all design levels, this leads to a so called ‘role plan’, which describes how the ambition level will be met, which missions and tasks will be carried out, which organisation structures and working process will be used, which people are carrying out the tasks and what technological support is available. For all choices, effectiveness and costs are given.

2.8 Using the framework

As indicated already, the frame work can be used for various design and evaluation processes ranging from new platform design to the redesign within platform modernisation programmes and evaluating existing platforms.

A typical way to go through the model for new platform design is the top-down approach. Starting with the strategic ambition, the functional demands are derived. Based on these functional demands, the conceptual design phase starts by creating and evaluating conceptual designs and deciding which conceptual design is the most cost effective. Based on the best conceptual design, the detailed design is developed. This approach is suitable for research questions with an open and innovative character when new concepts are not limited by details and budget. The approach is illustrated in the left flowchart of Figure 3.

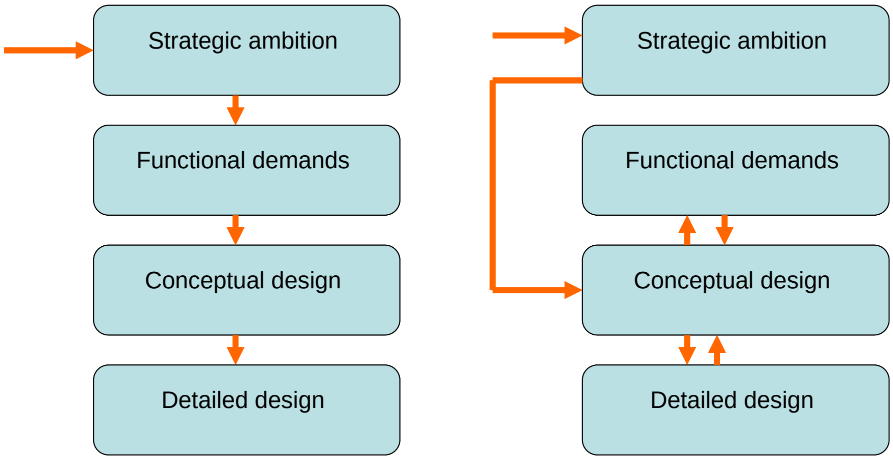

Figure 3: Top-down approach (left) and iterative approach (right).

However in practice an unlimited design process is less realistic. Strategic ambitions may cause limitations at various levels and limits on crew size and the budget for technology development cause limitations on the possible solutions. This indicates that a design process is an iterative process by nature, which means that the various phases have to be run through iteratively as well. The strategic ambition of the RNLN with respect to the platform is usually fixed when the design process starts. Starting with the design process itself is possible at the functional demands level, but also at the conceptual design phase. The strategic ambition (e.g. constrained crew size or high technology level) might induce the need for new manning concepts. In this situation, the conceptual design phase is the starting point of the design process (see the right side of Figure 3).

The concepts developed at the conceptual design level are not only evaluated on costs and effectiveness at this level, but also on the implications on functional demands level (i.e. can the functional demands still be met?). A conceptual design leads to the consideration of suitable detailed designs. Infeasibilities at one of the level lead to an adjustment of the original design and the phases have to be run through again. The detailed design phase will usually not be the final step.

In this way, the phases are run through in an iterative way until a design has been found which matches the constraints and strategic and functional ambitions.

3 SIMULATION BASED PERFORMANCE ASSESSMENT (SBPA) METHODOLOGY

This section introduces the SBPA methodology and shows its relation to other approaches.

The SBPA methodology allows a transparent, unbiased and integral performance assessment of (future) platforms. It defines an evaluation methodology to assess the overall performance of a platform to support the acquisition process. It is based on Multi Criteria Analysis (MCA) and simulation techniques.

The US DoD has developed the Cost and Operational Effectiveness Analysis (COEA) approach [1]. The goal of COEA is to perform a cost-benefit analysis to support acquisition decisions. Important aspects of the COEA approach are the problem definition, determining alternative system concepts, defining system requirements and MOEs, defining scenarios, data collection and model selection, and estimating costs and operational effectiveness of the possible system concepts.

Based on the COEA, the Integrated Cost and Operational Effectiveness Approach (ICEA) was developed, in the NATO Future Reduced Cost Combatant study [2]. The ICEA analyses design alternatives in the early design stage using operational effectiveness and life cycle cost. It defines scenarios and missions, and it develops a mission task tree. The operational effectiveness is calculated using the Operational Value Model (OVM) [3]. The survivability and sustainability are calculated separately. ICEA combines the operational effectiveness and the survivability and sustainability into an overall Figure of Merit (FOM) for the platform using the MCA Analytic Hierarchy Process [4].

Both OVM and ICEA use an aggregation method to combine the different MOEs into operational effectiveness and an overall performance of the platform. These aggregation methods are common to Multi Criteria Analysis (MCA) [5]. MCA is a scientific evaluation method for making rational choices between several discrete alternatives. It evaluates and compares the alternatives to obtain an aggregated assessment which results in a ranking of the alternatives. Typical for most MCA processes are preparing an evaluation structure (model) and dealing with the subjective preferences of one or more stakeholders involved and the processing of information from diverse and diffuse nature and origin (conflicting, quantitative and qualitative, inexact and uncertain, et cetera).

The SBPA methodology leverages these approaches and uses the following elements in particular to establish a structured process:

- the COEA approach
- mission-task analysis (ICEA and OVM)
- simulation models with different levels of aggregation and fidelity
- MCA techniques for weighing and comparing the different components

The SBPA methodology consists of five phases each consisting of several steps, see also Figure 4. We will now give a short overview of the five phases. A detailed description of the step by step plan can be found in [6].

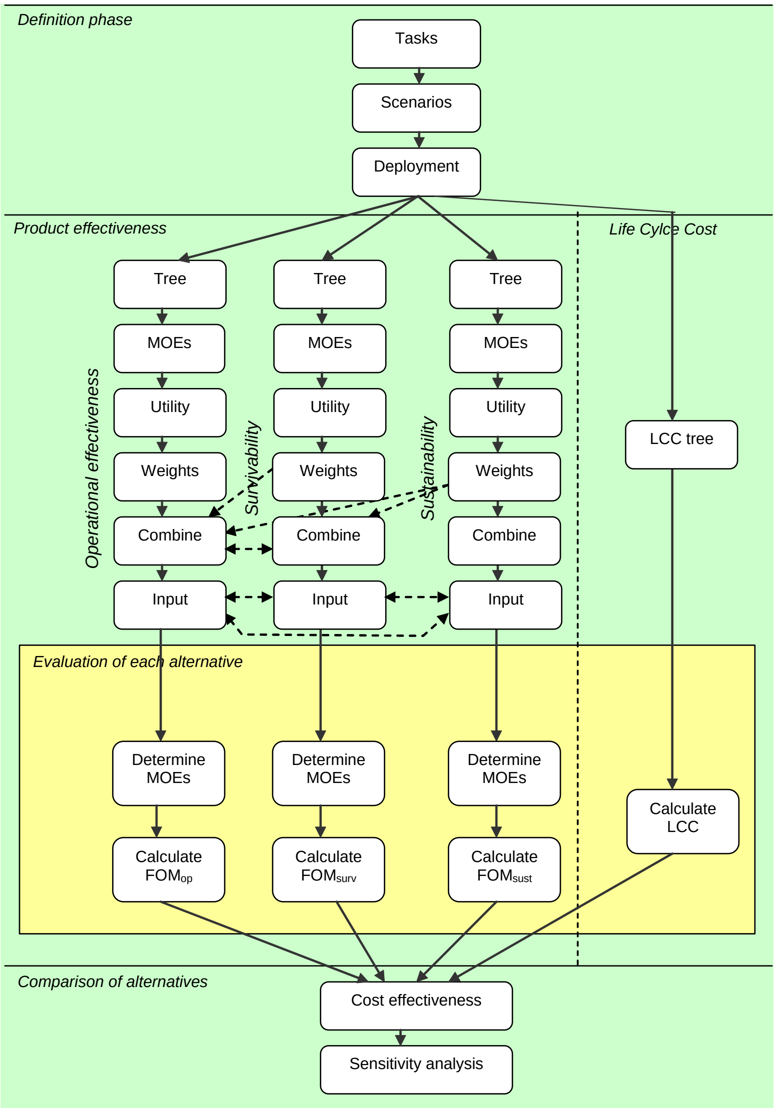

Figure 4: SBPA methodology step by step plan.

3.1 Phase 1: Definition phase

In this phase the operating conditions of the platform are defined: the expected missions and tasks that will be carried out by the platform under consideration as well as the expected scenarios in which the platform operates are described. Since exercises are an important part of the usage of a platform, they should be taken into account to properly determine sustainability and cost.

During the definition phase a structured description of the assumptions made and expected scenarios is produced.

3.2 Phase 2: Product effectiveness

In the second phase the evaluation framework is developed. An important part of the evaluation framework consists of determining the overall effectiveness of the platform, the so-called product effectiveness. Product effectiveness consists of three parts: operational effectiveness, survivability and sustainability. These are defined as:

- Operational effectiveness: The ability to perform military, diplomatic, police and humanitarian missions and tasks.
- Survivability: The ability to sail and fight after suffering an attack and the accumulation of battle damage.
- Sustainability: The ability to ensure the availability of propulsion, manoeuvrability, weapon, sensor and support systems to keep the platform operational.

For each of these parts, the criteria that are to be evaluated are placed in an MCA tree. An MCA tree contains both the criteria on which a design will be assessed and the relationships between these criteria. For the operational effectiveness, this tree is usually called a mission task tree, because this tree describes the relations between scenarios, missions and tasks and their relative importance, given by weights that are determined in general by expert opinion. For sustainability, criteria such as reliability, maintainability, required personnel and spare parts are commonly used.

For each criterion, one or more Measures of Effectiveness (MOEs) are formulated to evaluate the performance of the platform on this criterion. Also, it is determined how the MOEs are translated to a common scale, by using utility functions. In this way, MOEs can be meaningfully combined.

This evaluation framework is setup in advance, in order to avoid bias in the evaluation process. This framework enables a smooth evaluation process for the various design variants. Because all evaluation aspects are now described, new design variants can be added later on, following the same procedure. Moreover, it enables a fair comparison of alternatives.

A part of the setup of the evaluation framework is the decision how the product effectiveness of a design is determined, i.e. using expert opinion, simulation or analytical models. Simulation models are an invaluable tool. However, careful consideration is needed regarding the choice of input parameters and variations in the simulation input to ensure that the simulation results are representative for the real effectiveness of the platform.

3.3 Phase 3: Life Cycle Costs

The third phase defines how the Life Cycle Costs (LCC) are determined [7]. The LCC of a new platform can be divided into 6 main categories:

- Design
- Development
- Production
- Operating
- Support
- Disposal

Each category consists of a number of subcategories for which the costs can be determined in various ways and with various levels of detail.

The three cost estimation methods that are used mostly are ‘analogy’, ‘parametric’ and ‘engineering’. All these methods can be used in the SBPA methodology.

The *analogy* method compares a new system (design) with one or more existing systems and does not only take into account technical differences, but also differences in use and/or maintenance concepts.

The *parametric* method estimates the cost based on various measurable properties of the system. It is based on the existence of a causal relationship between system cost and system properties.

Unlike the parametric method, in the *engineering* method the formulas are based on the detailed consideration of the system and its use, and the relations between them. This method requires detailed design information.

3.4 Phase 4: Evaluation of each alternative

The first three phases have defined the evaluation framework that will be used in this phase to assess the performance and life cycle cost for each of the alternatives. In this way the alternatives can each be assessed in an identical manner.

This phase determines the actual performance for each of the alternatives. Using the results of Phase 2, it calculates values for each of the defined MOEs, and it aggregates these MOE values into Figures of Merit (FOMs) for each of the three product effectiveness parts. This may involve simulation as well as using expert opinions. And, using the results of phase 3, it performs the calculation of the LCC.

3.5 Phase 5: Analysis of results and comparison of alternatives

In the final phase the results are analysed, the alternatives are compared on product effectiveness and costs and a sensitivity analysis is carried out to determine the robustness of the results.

3.6 Use of the SBPA methodology

When using the SBPA methodology, it is important to pay thorough attention to each of the steps. Putting down in writing the steps followed and choices made, as well as the model input, is essential for a proper evaluation and comparison of design.

Although it may be difficult, it is important to describe the operational context of the platform adequately. This includes for example, the life cycle, characteristics of the areas of operation and of the behaviour (tactics, level of aggression) of opponents and own platforms. Care must be taken that the assumptions that are made have a broad coverage and are plausible at the same time.

As applying the SBPA methodology is quite time consuming, it is recommended to determine timely the required level of detail. For example, if the contribution of one task to the overall FOM is very low, because of the low weights for this task and the missions it belongs to, it should be considered to address this task in less detail, i.e. with less effort.

The 'definition phase' specifies the input for generating MOEs for the different tasks. However extra assumptions have to be made when setting up and executing the simulations, for example, many additional assumptions are made regarding environmental conditions and system parameters. These assumptions must be recorded and consistency among them must be assured.

The sensitivity and uncertainty analysis during the comparison of alternatives is a very important part of the methodology. It provides insight in the robustness of the performance assessment.

The SBPA methodology can be used in an iterative way to find better platform designs. Starting with a limited number of designs, the evaluation can be used to generate improved designs. These hopefully improved designs can be evaluated by going through Step 4 and 5 of the methodology again. Note that the first three steps are describing how the evaluation should be carried out. In this iterative way, improved designs can be found.

4 INTERACTION BETWEEN MANNING CONCEPT FRAMEWORK AND SBPA METHODOLOGY

The design of a new ship comprises both the ship structure and characteristics and the manning on board the ship. Choices made regarding the required capabilities of the new platform, the platform design and the manning concept interact with each other.

The manning concept framework is primarily meant for – as the name indicates – the development and evaluation of manning concepts. However, the structure with various levels of detail is also valid for the technical design of a new platform. Strategic ambitions form the starting points of every design process. The SBPA methodology focuses on the evaluation of the operational performance and life cycle costs at platform level, i.e. the functional demands level. Examples of design decision at this level are the maximum speed of the platform, the availability of a helicopter, the signature and sensor and weapon systems. At conceptual design level the design aspects are focussed on parts of the ship and ways to obtain the specifications of the functional demands. An example is the concept of signature reduction measures that result in the signature given at functional demands level.

Technical aspects should be closely related and should even be part of the manning concepts when for instance automation, technical support and centralisation enables different ways of task executions and crew configurations. Hence, new manning concepts must come together with technological developments and innovations. As shown in Section 2, the manning concept framework takes technical aspects into account. The starting point of the manning concept framework, however, is a human centred and conceptual driven design process. Of course, redesign may well start with a technology push. But in cases like that, the human dimension of the system should be re-designed and adjusted accordingly. This shows that manning concepts, technological developments and ship design are closely related. The operational performance is a combination of technological innovations, i.e. the platform design, at the implemented manning concept. Figure 5 shows the relationships in the ship design process.

For the evaluation of the manning concept framework at functional demands level the SBPA methodology is an excellent tool. At conceptual and detailed design level, evaluation often occurs in a qualitative way by comparing alternatives and indicating if an alternative performs (much) better or worse. Simulation models to obtain quantitative measure are hardly available.

As mentioned before, the design process of a new platform is an iterative process. This does not only hold for the construction of a manning concept, but also for the design of the platform itself. Platform design and manning concept development interact with each other. New technical systems might change the working process and the number of crew members required for a certain task. The size of the ship and the facilities on board must be enough to accommodate the required manning.

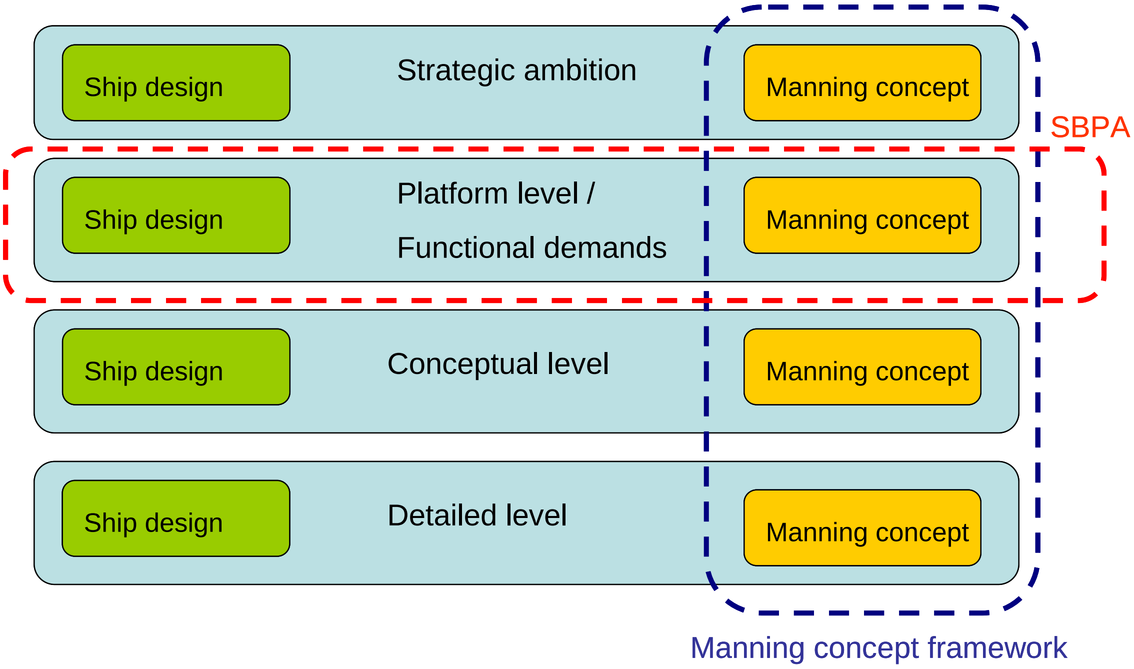

Figure 5: Place of the methodologies in the ship design process.

5 CONCLUSIONS

In this paper we have presented the manning concept framework and the SBPA methodology developed by TNO. The combination of methodology and framework assist the design process in evaluating design concepts during the acquisition process and for upgrades of existing platforms at various design levels. Many aspects that are relevant for the assessment of new concepts are taken into account: operational effectiveness, survivability, sustainability, life cycle costs and the performance and the well-being of the crew members.

Although both methodology and framework have clear added value, they do not provide an easy recipe that can be followed blindly. The construction of new platform designs and manning concepts remains both a creative and decision-making process that is supported by methodology and framework. They do not replace the creative process and do not deliver ready-made designs.

The manning concept framework provides an extensive overview of components that are relevant during the design or evaluation process, mainly on manning concepts. The framework forces the designer to consider choices and their consequences in such a way that infeasible or expensive solutions and unexpected possibilities should become clear at an early stage of the process.

The SBPA methodology is a suitable methodology for executing performance assessment of new platforms and systems as well as during maintenance and upgrade programs. Based on our experiences we believe that the use of the SBPA methodology leads to better choices and improves the transparency during the acquisition process.

Both methodology and framework help to found and defend choices and decisions in the evaluation process by providing a structure that forces the designer to consider all relevant aspects. They serve as a tool to secure available knowledge. Furthermore they provide insight in (operational and financial) consequences of design choices.

The combination of the manning concept framework and the SBPA methodology provides a powerful tool to support the designer of new platforms during the evaluation of new designs, both technically and manning based, on performance and costs.

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